EXHIBIT E

Part 1 of 2

US005495607A

United States Patent [19]

Pisello et al.

[11] **Patent Number: 5,495,607**

[45] **Date of Patent: Feb. 27, 1996**

[54] **NETWORK MANAGEMENT SYSTEM HAVING VIRTUAL CATALOG OVERVIEW OF FILES DISTRIBUTIVELY STORED ACROSS NETWORK DOMAIN**

[75] Inventors: **Thomas Pisello**, De Bary; **David Crossmier**, Casselberry; **Paul Ashton**, Oviedo, all of Fla.

[73] Assignee: **Conner Peripherals, Inc.**, San Jose, Calif.

[21] Appl. No.: **153,011**

[22] Filed: **Nov. 15, 1993**

[51] **Int. Cl.**[6] **G06F 11/30**; G06F 13/00; G06F 15/16

[52] **U.S. Cl.** **395/600**; 395/200.01; 395/650; 395/800; 395/280; 395/180; 364/229.5; 364/242.96; 364/DIG. 1; 364/974.2; 364/DIG. 2

[58] **Field of Search** 364/200; 395/200, 395/600, 650, 325, 575

[56] **References Cited**

U.S. PATENT DOCUMENTS

4,141,006	2/1979	Braxton	379/40
4,710,870	12/1987	Blackwell et al.	395/575
4,805,134	2/1989	Calo et al.	395/600
4,897,841	6/1990	Gang, Jr.	370/85.13
4,914,571	4/1990	Baratz et al.	395/600
4,987,531	1/1991	Nishikado et al.	395/600
5,001,628	3/1991	Johnson et al.	395/600
5,077,658	12/1991	Bendert et al.	395/600
5,133,075	7/1992	Risch	395/800
5,163,131	11/1992	Row et al.	395/200
5,175,852	12/1992	Johnson et al.	395/600
5,216,591	6/1993	Nemirovsky et al.	395/200
5,220,562	6/1993	Takada et al.	370/85.13
5,247,670	9/1993	Matsunaga	395/650
5,271,007	12/1993	Kurahashi et al.	395/600
5,287,453	2/1994	Roberts	395/200
5,287,461	2/1994	Moore	395/275
5,295,244	3/9194	Deu et al.	395/200
5,325,527	6/1994	Cwikowski et al.	395/650

OTHER PUBLICATIONS

Sudhaka et al., "Design and performance evaluation considerations of multimedia medical database". IEEE, Oct. 1993, pp. 888–894.

Robinson et al. "Domain: a New approach to distributed system management", IEEE, 1988, 154–163.

News clip regarding "File Wizard" product.

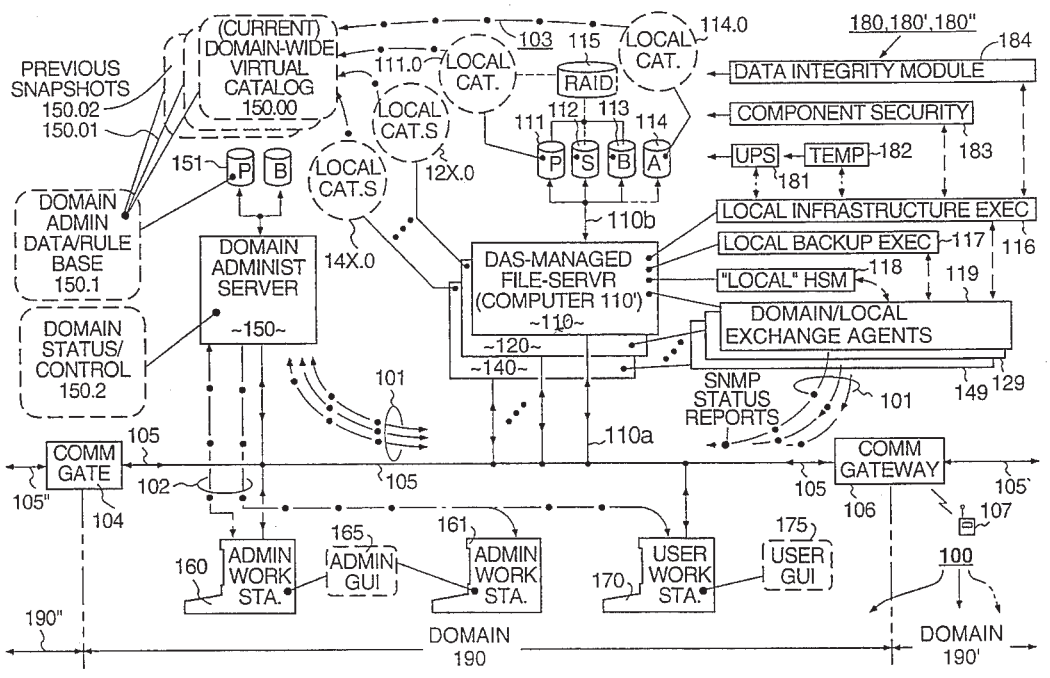
News clip regarding "LAN Auditor 3.0" product.

Primary Examiner—Thomas G. Black
Assistant Examiner—Cuan Pham
Attorney, Agent, or Firm—Fliesler, Dubb, Meyer & Lovejoy

[57] **ABSTRACT**

A network management system includes a domain administrating server (DAS) that stores a virtual catalog representing an overview of all files distributively stored across a network domain currently or in the past. The current and historical file information is used for assisting in auditing or locating files located anywhere in the domain. The current file information is used for assisting in transferring files across the domain. The domain administrating server (DAS) also includes a rule-base driven artificial administrator for monitoring and reacting to domain-wide alert reports and for detecting problematic trends in domain-wide performance based on information collected from the network domain.

23 Claims, 4 Drawing Sheets



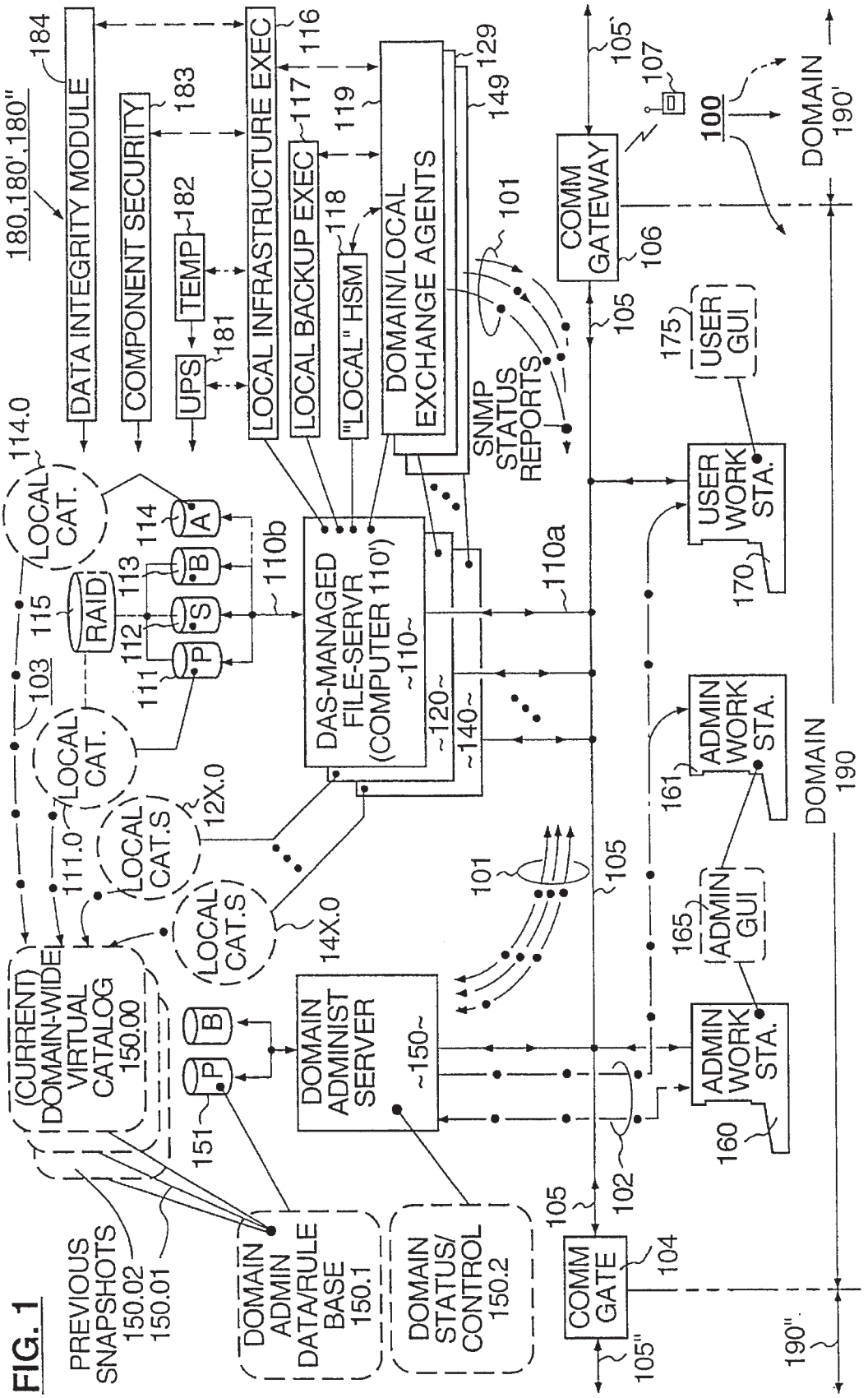

180,180',180"
184
DATA INTEGRITY MODULE
COMPONENT SECURITY
183
UPS
TEMP
182
181
LOCAL INFRASTRUCTURE EXEC
116
LOCAL BACKUP EXEC
117
"LOCAL" HSM
118
119
DOMAIN/LOCAL EXCHANGE AGENTS
129
149
101
SNMP STATUS REPORTS
114.0
LOCAL CAT.
RAID
113
114
A
B
S
P
112
111
115
103
110b
DAS-MANAGED FILE-SERVR (COMPUTER 110')
~110~
~120~
~140~
110a
COMM GATEWAY
105'
107
106
105
100
DOMAIN 190'
USER GUI
175
USER WORK STA.
170
ADMIN WORK STA.
161
ADMIN GUI
165
ADMIN WORK STA.
160
DOMAIN 190
111.0
LOCAL CAT.S
12X.0
14X.0
(CURRENT) DOMAIN-WIDE VIRTUAL CATALOG 150.00
PREVIOUS SNAPSHOTS 150.02 150.01
151
DOMAIN ADMINIST SERVER
~150~
DOMAIN ADMIN DATA/RULE BASE 150.1
DOMAIN STATUS/ CONTROL 150.2
COMM GATE
104
102
105"
190"

FIG. 1

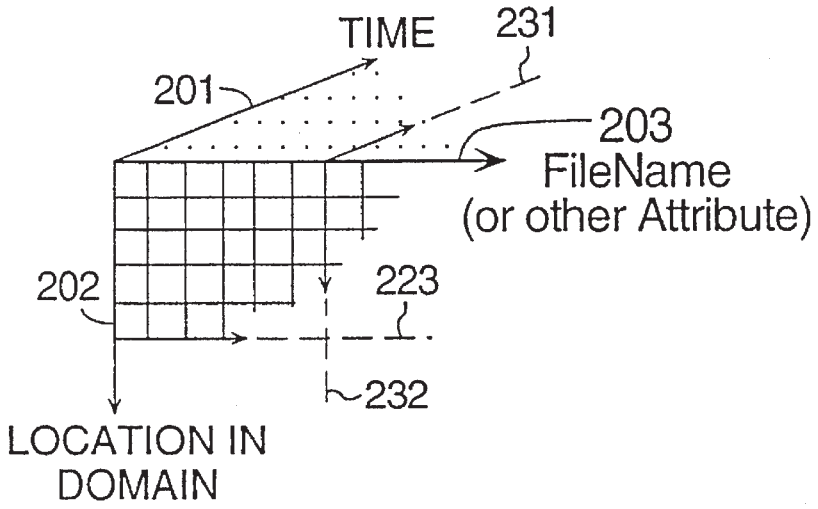


FIG. 2

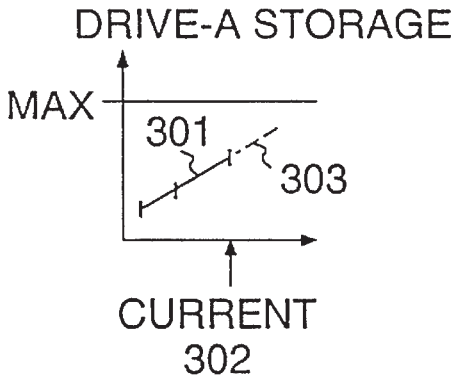


FIG. 3A

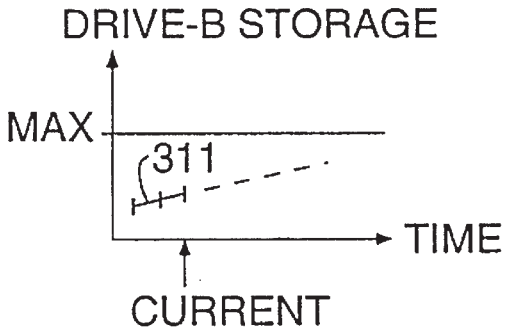


FIG. 3B

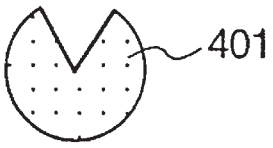
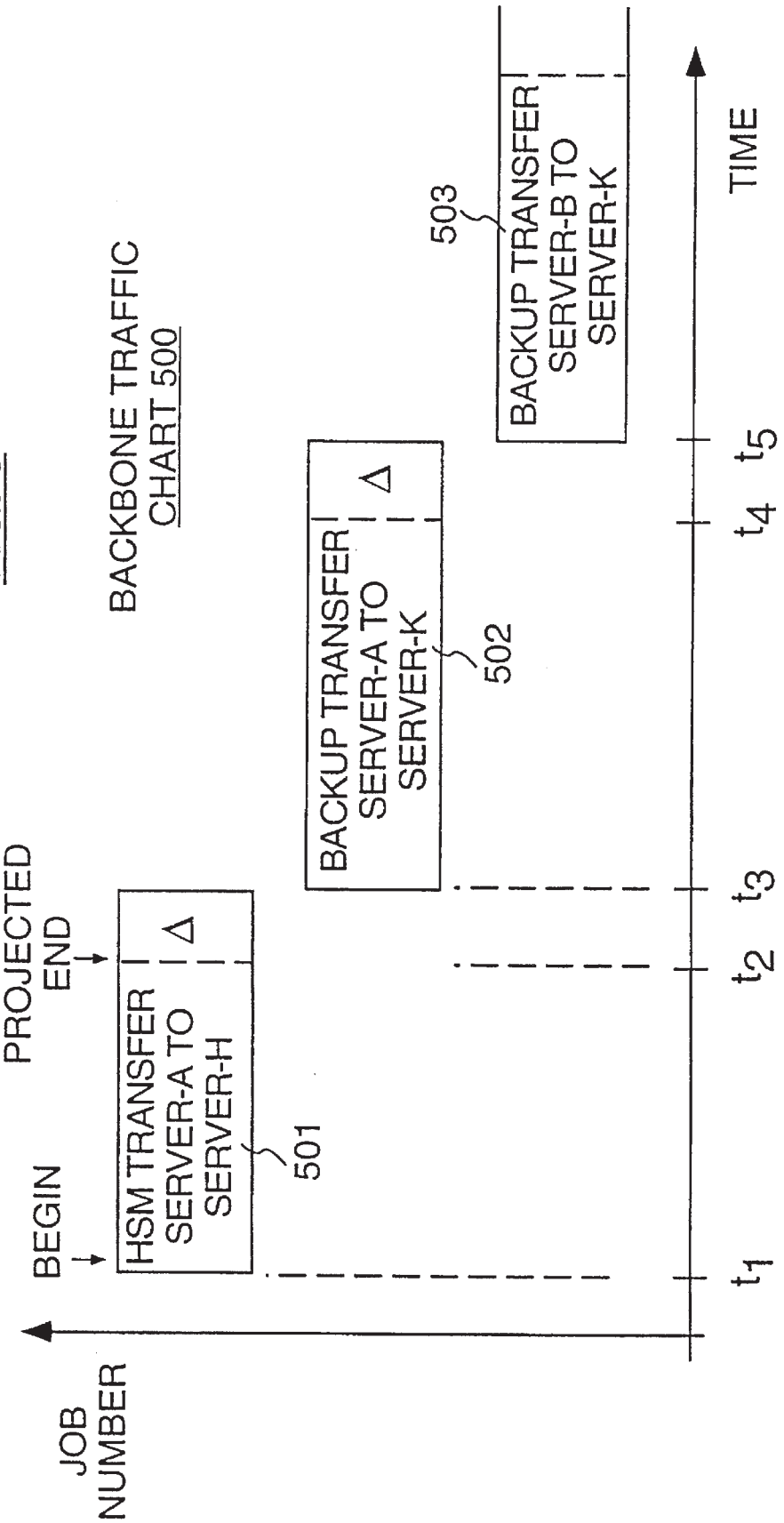


FIG. 4A

FIG. 4B

FIG. 5


BACKBONE TRAFFIC
CHART 500
JOB NUMBER
TIME
BEGIN
PROJECTED END
HSM TRANSFER SERVER-A TO SERVER-H
501
BACKUP TRANSFER SERVER-A TO SERVER-K
502
BACKUP TRANSFER SERVER-B TO SERVER-K
503
Δ
Δ
t_1
t_2
t_3
t_4
t_5

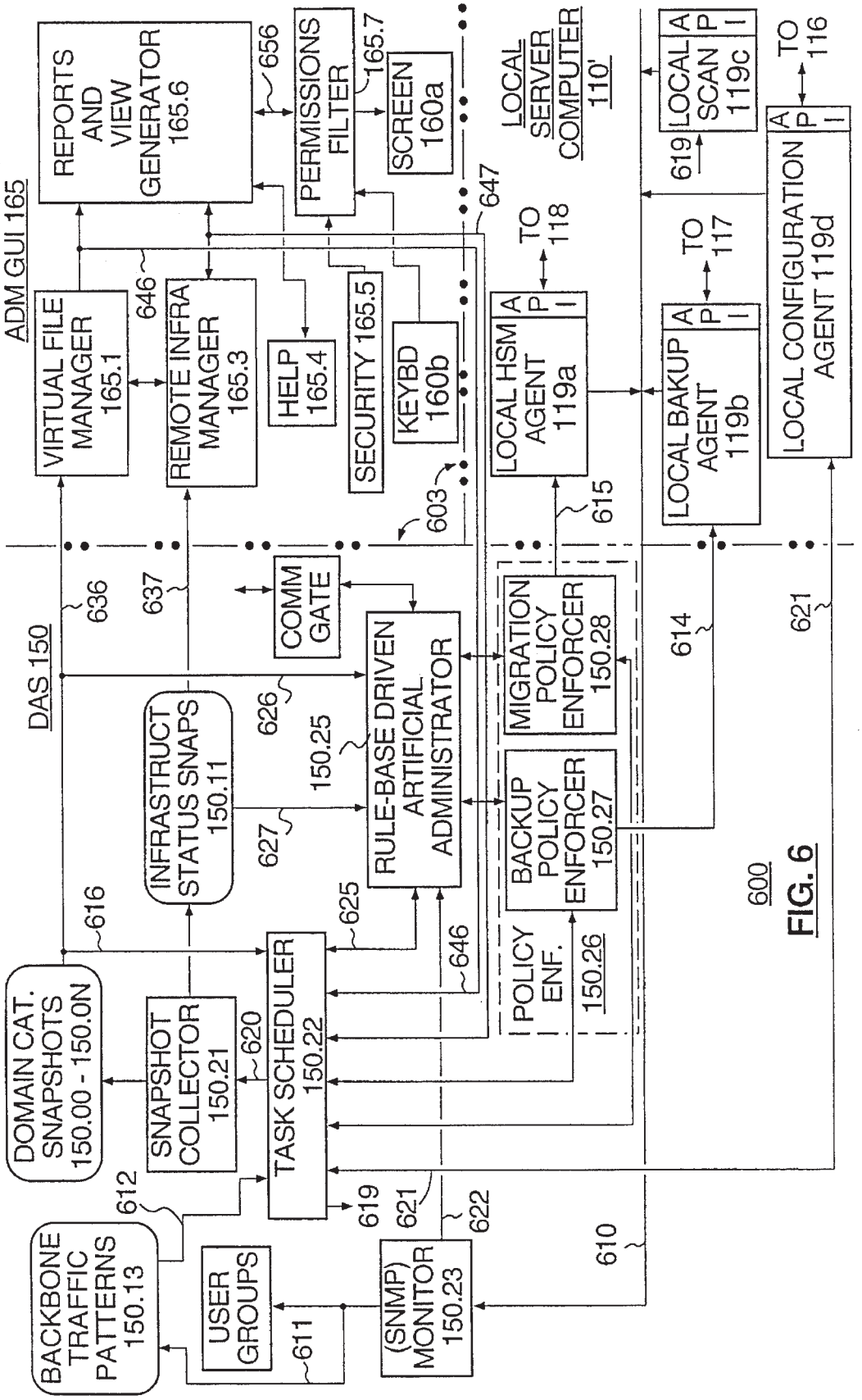

ADM GUI 165
REPORTS AND VIEW GENERATOR 165.6
656
PERMISSIONS FILTER
165.7
SCREEN 160a
LOCAL SERVER COMPUTER 110'
LOCAL SCAN 119c
619
TO 116
VIRTUAL FILE MANAGER 165.1
646
REMOTE INFRA MANAGER 165.3
HELP 165.4
SECURITY 165.5
KEYBD 160b
647
603
LOCAL HSM AGENT 119a
TO 118
LOCAL BAKUP AGENT 119b
TO 117
LOCAL CONFIGURATION AGENT 119d
DAS 150
636
637
COMM GATE
615
614
621
626
150.25
627
INFRASTRUCT STATUS SNAPS 150.11
RULE-BASE DRIVEN ARTIFICIAL ADMINISTRATOR
MIGRATION POLICY ENFORCER 150.28
BACKUP POLICY ENFORCER 150.27
POLICY ENF. 150.26
625
646
616
DOMAIN CAT. SNAPSHOTS 150.00 - 150.0N
SNAPSHOT COLLECTOR 150.21
620
TASK SCHEDULER 150.22
612
619
621
622
610
BACKBONE TRAFFIC PATTERNS 150.13
USER GROUPS
611
(SNMP) MONITOR 150.23
600

FIG. 6

NETWORK MANAGEMENT SYSTEM HAVING VIRTUAL CATALOG OVERVIEW OF FILES DISTRIBUTIVELY STORED ACROSS NETWORK DOMAIN

BACKGROUND

1. Field of the Invention

The invention relates generally to the field of computerized networks. The invention relates more specifically to the problem of managing a system having a variety of file storage and file serving units interconnected by a network.

2. Cross Reference to Related Applications

The following copending U.S. patent application(s) is/are assigned to the assignee of the present application, is/are related to the present application and its/their disclosures is/are incorporated herein by reference:

(A) Ser. No. 08/151,525 [Attorney Docket No. CONN8675] filed Nov. 12, 1993 by Guy A. Carbonneau et al and entitled, SCSI-COUPLED MODULE FOR MONITORING AND CONTROLLING SCSI-COUPLEDHAID BANK AND BANK ENVIRONMENT;

3. Description of the Related Art

Not too long ago, mainframe computers were the primary means used for maintaining large databases. More recently, database storage strategies have begun to shift away from having one large mainframe computer coupled to an array of a few, large disk units or a few, bulk tape units, and have instead shifted in favor of having many desktop or mini- or micro-computers intercoupled by a network to one another and to many small, inexpensive and modularly interchangeable data storage devices (e.g., to an array of small, inexpensive, magnetic storage disk and tape drives).

One of the reasons behind this trend is a growing desire in the industry to maintain at least partial system functionality even in the event of a failure in a particular system component. If one of the numerous mini/micro-computers fails, the others can continue to function. If one of the numerous data storage devices fails, the others can continue to provide data access. Also increases in data storage capacity can be economically provided in small increments as the need for increased capacity develops.

A common configuration includes a so-called "client/server computer" that is provided at a local network site and has one end coupled to a local area network (LAN) or a wide area network (WAN) and a second end coupled to a local bank of data storage devices (e.g., magnetic or optical, disk or tape drives). Local and remote users (clients) send requests over the network (LAN/WAN) to the client/server computer for read and/or write access to various data files contained in the local bank of storage devices. The client/server computer services each request on a time shared basis.

In addition to performing its client servicing tasks, the client/server computer also typically attends to mundane storage-management tasks such as keeping track of the amount of memory space that is used or free in each of its local storage devices, maintaining a local directory in each local storage device that allows quick access to the files stored in that local storage device, minimizing file fragmentation across various tracks of local disk drives in order to minimize seek time, monitoring the operational status of each local storage device, and taking corrective action, or at least activating an alarm, when a problem develops at its local network site.

Networked storage systems tend to grow like wild vines, spreading their tentacles from site to site as opportunities present themselves. After a while, a complex mesh develops, with all sorts of different configurations of client/server computers and local data storage banks evolving at each network site. The administration of such a complex mesh becomes a problem.

In the early years of network management, a human administrator was appointed for each site to oversee the local configuration of the on-site client/server computer or computers and of the on-site data storage devices.

In particular, the human administrator was responsible for developing directory view-and-search software for viewing the directory or catalog of each on-site data storage device and for assisting users in searches for data contained in on-site files.

The human administrator was also responsible for maintaining backup copies of each user's files and of system-shared files on a day-to-day basis.

Also, as primary storage capacity filled up with old files, the human administrator was asked to review file utilization history and to migrate files that had not been accessed for some time (e.g., in the last 3 months) to secondary storage. Typically, this meant moving files that had not been accessed for some time, from a set of relatively-costly high-speed magnetic disk drives to a set of less-costly slower-speed disk drives or to even slower, but more cost-efficient sequential-access tape drives. Very old files that lay unused for very long time periods (e.g., more than a year) on a "mounted" tape (which tape is one that is currently installed in a tape drive) were transferred to unmounted tapes or floppy disks and these were held nearby for remounting only when actually needed.

When physical on-site space filled to capacity for demounted tapes and disks, the lesser-used ones of these were "archived" by moving them to more distant physical storage sites. The human administrator was responsible for keeping track of where in the migration path each file was located. Time to access the data of a particular file depended on how well organized the human administrator was in keeping track of the location of each file and how far down the chain from primary storage to archived storage, each file had moved.

The human administrator at each network site was also responsible for maintaining the physical infrastructure and integrity of the system. This task included: making sure power supplies were operating properly, equipment rooms were properly ventilated, cables were tightly connected, and so forth.

The human administrator was additionally responsible for local asset management. This task included: keeping track of the numbers and performance capabilities of each client/server computer and its corresponding set of data storage devices, keeping track of how full each data storage device was, adding more primary, secondary or backup/archive storage capacity to the local site as warranted by system needs, keeping track of problems developing in each device, and fixing or replacing problematic equipment before problems became too severe.

With time, many of the manual tasks performed by each on-site human administrator came to be replaced, one at a time on a task-specific basis, by on-site software programs. A first set of one or more, on-site software programs would take care of directory view-and-search problems for files stored in the local primary storage. A second, independent set of one or more, on-site software programs would take

care of directory view-and-search problems for files stored in the local secondary or backup storage. Another set of one or more, on-site software programs would take care of making routine backup copies and/or routinely migrating older files down the local storage migration hierarchy (from primary storage down to archived storage). Yet another set of on-site software programs would assist in locating files that have been archived. Still another set of independent, on-site software programs would oversee the task of maintaining the physical infrastructure and integrity of the on-site system. And a further set of independent, on-site software programs would oversee the task of local asset management.

The term "task-segregation" is used herein to refer to the way in which each of the manual tasks described above has been replaced, one at a time by a task-specific software program.

At the same time that manual tasks were being replaced with task-segregated software programs, another trend evolved in the industry where the burden of system administration was slowly shifted from a loose scattering of many local-site, human administrators ——one for each site—— to a more centralized form where one or a few human administrators oversee a large portion if not the entirety of the network from a remote site.

This evolutionary movement from local to centralized administration, and from task-segregated manual operation to task-segregated automated operation is disadvantageous when viewed from the vantage point of network-wide administration. The term "network-wide administration" is used here to refer to administrative tasks which a human administrator located at a central control site may wish to carry out for one or more client/server data storage systems located at remote sites of a large network.

A first major problem arises from the inconsistency among user interfaces that develops across the network. In the past, each local-site administrator had a tendency to develop a unique style for carrying out man-to-machine interactions. As a result, one site might have its administrative programs set up to run through a graphical-user interface based on, for example the Microsoft Windows™ operating environment, while another site might have its administrative programs running through a command-line style interface based on, for example the Microsoft DOS 6.0™ operating system or the AT&T UNIX™ operating system. A network-wide administrator has to become familiar with the user interface at each site and has to remember which is being used at each particular site in order to be able to effectively communicate with the local system administrating software programs. Inconsistencies among the interfaces of multiple network sites makes this a difficult task.

Another problem comes about from the task-segregated manner in which local administrative programs have developed over the years. A remote human administrator (or other user) has to become familiar with the local topology of each network site when searching for desired files. In other words, he or she has to know what kinds of primary, secondary, backup and archive storage mechanism are used at each site, how they are connected, how data files migrate through them, and which "file manager" program is to be used to view the files of each type of storage mechanism.

More specifically, if a file cannot be found in the directory of a primary storage device located at a particular network site, the administrator has to switch from the primary storage viewing program to a separate, migration-tracking program to see if perhaps the missing file has been migrated to secondary or archive storage at that site. The administrator

may have to switch to a separate, backup-tracking program to see if a file that is missing from primary and secondary storage might be salvaged out of backup storage at the same or perhaps a different site. Sometimes, the administrator may wish to see a historical profile of a file in which revisions have been made to the file over a specified time period. A separate file-history tracking program at the site might have to be consulted, if it exists at all, to view such a historical profile.

If a file cannot be found at a first site then perhaps a copy might be stored at another site. To find out if this is the case, the administrator has to log out of the first site, log-in to the system at a next site and repeat the above process until the sought after data is located or the search is terminated.

Each switch from one site to a next, and from one independent file-managing program to another disadvantageously consumes time and also introduces the problem of inconsistent user interfaces.

A similar set of problems is encountered in the overseeing of lower-level infrastructure support operations of a networked data storage system. Included in this category are the scheduling and initiation of routine file backup and file migration operations at each site, the tracking of problems at each site and so forth.

A method and system for integrating all the various facets of system administration on a network-wide basis is needed.

SUMMARY OF THE INVENTION

The invention overcomes the above-mentioned problems by providing a network management system having virtual catalog overview function for viewing of files distributively stored across a network domain.

A network management system in accordance with the invention comprises: (a) a domain administrating server (DAS) coupled to a network-linking backbone of a network domain for scanning the network domain to retrieve or broadcast domain-wide information, where the domain administrating server (DAS) has means for storing and maintaining a domain-wide virtual catalog and for overseeing other domain-wide activities, and where the domain-wide virtual catalog contains file identifying information for plural files distributively stored in two or more file servers of the network domain; and (b) one or more workstations, coupled by way of the network-linking backbone to the domain administrating server for accessing the domain-wide information retrieved by the domain administrating server.

A method in accordance with the invention comprises the steps of: (a) interrogating the local catalog of each data storage device in a network composed of plural data storage devices linked to one another by a network-linking backbone, (b) retrieving from each interrogated local catalog, file identifying information identifying a name, a storage location and/or other attributes of each file stored in the interrogated device; and (c) integrating the retrieved file identifying information collected from each local catalog into a domain-wide virtual catalog so that each file stored on the network can be identified by name, location an/or another attribute by consulting the domain-wide virtual catalog.

BRIEF DESCRIPTION OF THE DRAWINGS

The below detailed description makes reference to the accompanying drawings, in which:

FIG. **1** is a block diagram showing a centralized domain management system in accordance with the invention;

FIG. **2** is a perspective view of a multi-dimensional viewing window for visualizing domain-wide activities spatially, temporally and by file attributes;

FIGS. **3A–3B** show a set of trend analysis graphs that may be developed from the domain-wide, virtual catalog snapshots obtained by the system of FIG. **1**;

FIGS. **4A–4B** show side-by-side examples of pie charts showing used-versus-free storage space on respective storage drives DRIVE-A and DRIVE-B within the domain of FIG. **1**;

FIG. **5** a job scheduling chart for minimizing traffic congestion on the network-linking backbone; and

FIG. **6** shows a logical flow map between various data and control mechanisms distributed amongst the domain administrating server (DAS), an administrative workstation, and a given server computer.

DETAILED DESCRIPTION

FIG. **1** is a block diagram of a networked enterprise system **100** in accordance with the invention.

Major components of the networked enterprise system **100** include: a network-linking backbone **105**, a plurality of DAS-managed file-servers **110**, **120**, . . . , **140**, operatively coupled to the backbone **105**; and a domain administrating server (DAS) **150** also operatively coupled to the backbone **105**.

The network-linking backbone **105** can be of any standard type used for forming local-area or wide-area digital data networks (or even metropolitan wide networks). Examples of standard backbones include Ethernet coaxial or twisted pair cables and token ring systems.

One or more communication gateways **104**, **106** can link the illustrated backbone **105** to additional backbones **105'**, **105"**. The communications gateways **104**, **106** may be of the wired type (e.g., high-speed digital telephone lines) or a wireless type (e.g. microwave or satellite links). As such the overall communications network -**105"-104-105-106-105'**- etc., can extend over long distances and pass through many geographic sites. Examples include communication networks which interlink different offices of a large building complex, or those which interlink multiple buildings of a campus, or those which interlink campuses of different cities or those that interlink transcontinental or global sites.

For purposes of administration, it is convenient to call the overall communications network -**105"-104-105-106-105'**- etc., and the resources connected to it, an "enterprise". It is convenient to subdivide the enterprise into a plurality of nonoverlapping "domains". The domains are logical subdivisions but may follow physical subdivisions. Examples of such subdivisions include but are not limited to: (a) subdividing a building-wide enterprise into floor-wide domains, one for each floor; (b) subdividing a corporate-wide enterprise into department-wide domains, one for each department of the corporate structure (e.g., accounting, marketing, engineering, etc.); (c) subdividing a multi-city enterprise according to the different cities it services; and so forth.

A block diagram of a first domain **190** within an enterprise system **100** in accordance with the invention is shown in FIG. **1**. The enterprise system **100** can be composed of the one illustrated domain **190** or may have a plurality of like-structured or differently-structured domains connected to the illustrated first domain **190**.

The aforementioned network-linking backbone **105** and plural file servers **110**, **120**, . . . , **140** are included within the first domain **190**. The domain administrating server (DAS) **150** is also included within the first domain **190** as are a plurality of administrative workstations **160**, **161**, etc., and a plurality of user workstations **170**, **171** (not shown), etc., which also connect to the network-linking backbone **105**.

Although not shown, it is to be understood that numerous other data input and/or output devices can be connected to the network-linking backbone **105**, including but not limited to: so-called "dumb" terminals which do not have a non-volatile mass storage means of their own, printers, label-makers, graphical plotters, modems, data acquisition equipment (analog-to-digital converters), digital voice and/or image processing equipment, and so forth. File-servers **110**, **120**, . . . , **140** may be used for storing or outputting the data created or used by these other data input and/or output devices.

Each file server **110**, **120**, . . . , **140** has associated with it: (1) a respective, local server computer **110'**, **120'**, . . . , **140'**; (2) a set of one or more nonvolatile data storage devices (e.g. **111–114**); and (3) a respective infrastructure **180**, **180'**, . . ., **180"** for supporting operations of the local server computer (e.g., **110'**) and its associated data storage devices (e.g. **111–114**).

It is to be understood that communications gateway **106** can be used to link the first domain **190** to a variety of other structures, including a subsequent and like-structured second domain **190'**. Similarly, communications gateway **104** can be used to link the first domain **190** to a variety of other structures, including a preceding and like-structured third domain **190"**. Data can be transferred from one domain to the next via the communications gateways **104**, **106**.

In addition to being able to communicate with other domains, each communications gateway **104**, **106** can link via telephone modem or by way of a radio link to remote devices such as an administrator's home computer or an administrator's wireless pager (beeper) **107** and send or receive messages by that pathway.

The internal structure of the first of the DAS-managed file servers, **110**, is now described as exemplary of the internal structures of the other DAS-managed file servers, **120**, . . ., **140**. The term "DAS-managed" indicates, as should be apparent by now, that each of file servers **110**, **120**, . . . , **140** is somehow overseen or managed by the Domain Administrating Server (DAS) **150**. Details of the oversight and/or management operations are given below.

The first DAS-managed file server **110** includes a client/server type of computer **110'** which is represented by box **110** and referred to herein as the "local server computer **110'**". Server computer **110'** is understood to include a CPU (central processing unit) that is operatively coupled to internal RAM (random access memory) and/or ROM (read-only memory). Examples of client/server type computers that form the foundation for server computer **110'** include off-the shelf tower-style computers that are based on the Intel 80486™ microprocessor and come bundled with appropriate client/server supporting hardware and software.

The local server computer **110'** of the first DAS-managed file-server **110** has a network interface port **110*a*** that operatively couples the server computer **110'** to the network-linking backbone **105** and a mass-storage port **110*b*** that operatively couples the server computer **110'** to one or more of: a primary mass storage means **111**, a slower secondary storage means **112**, a backup storage means **113**, and an archived-data storage and retrieval means **114**.

The primary storage means **111** can be a high speed Winchester-type magnetic disk drive or the like but can also

include battery-backed RAM disk and/or non-volatile flash-EEPROM disk or other forms of high-performance, non-volatile mass storage.

The secondary storage means **112**, if present, can include a slower WORM-style optical storage drive (Write Once, Read Many times) or a "floptical" storage drive or other secondary storage devices as the term will be understood by those skilled in the art. (Secondary storage is generally understood to cover mass storage devices that have somewhat slower access times than the associated primary storage but provide a savings in terms of the cost per stored bit.)

The backup storage means **113** can include magnetic disk drives but more preferably comprises DAT (Digital Audio Tape) drives or other forms of tape drives or other cost-efficient backup storage devices. A backup copy of each file held in primary or secondary storage (**111**, **112**) is preferably made on a periodic basis (e.g., nightly or every weekend) so that a relatively recent copy of a given file can be retrieved even in the case where the corresponding primary or secondary storage means (**111**, **112**) suffers catastrophic failure; e.g., a head crash or destruction.

The archived-data storage and retrieval means **114** typically comes in the form of an archive create/-retrieve drive and an associated set of removable tapes or removable disk cartridges. Most if not all of the associated set of removable archive tapes and/or removable archive disk cartridges are not physically mounted to the archive create/retrieve drive (as indicated by the dashed connection line) and are thus not immediately accessible to the server computer **110'**. They can be mounted when requested and thereafter accessed.

Note: The above description is intended to be generic of the types of nonvolatile mass storage means **111–114** that might be connected to the mass-storage port **110*b*** of the server computer **110'**. In theory, each server computer can have all of the primary (P), secondary (S), backup (B) and archive (A) storage means (**111–114**) connected to its mass-storage port **110*b***. Due to cost and performance considerations however, a typical set-up will instead have one or more "groups" of server computers to which primary but not secondary storage means is connected. Each such server computer will be referred to as a primary file server. A second set of server computers will have secondary but not primary storage means connected to them and will be each referred to as a secondary or "HSM" file server and will each service a particular "group" of primary file servers. A secondary file server is sometimes also referred to as a "storage server".

Backup storage means (e.g., a tape cartridge drive) may be provided either on a one-for-one basis for each server computer or one server computer might be dedicated for generating backup tapes/disks for a pre-assigned group of primary and/or secondary file servers.

Archive storage can be similarly configured on a one-for-one basis for each server computer or one server computer might be dedicated for creating and retrieving archive tapes/disks for an associated group of primary and/or secondary file servers.

The data files of the primary, secondary and backup storage means **111–113** can be organized conventionally or distributed redundantly across a plurality of drives in accordance with a practice known as RAID (Redundant Array of Inexpensive Data-storage drives). A detailed description of the intricacies involved in managing a RAID system may be found in the above-cited patent application, SCSI-COUPLED MODULE FOR MONITORING AND CONTROLLING SCSI-COUPLEDRAID BANK-AND-BANK ENVIRONMENT, which application is incorporated herein by reference. As such these will not be detailed here. In brief, each file is distributively stored across two or more storage drives so that failure of a single drive will not interfere with the accessibility or integrity of a stored file. The dashed symbol **115** for a RAID bank indicates the possibility of file distribution across redundant drives.

The above-cited application also details the intricacies involved in maintaining an infrastructure **180** for supporting various operations of the data storage devices **111–113** of a given server computer, and as such these will not be detailed here either. In brief, the infrastructure **180** of the server computer **110'** preferably includes an uninterruptible power supply means (UPS) **181** for supplying operational power to the local data storage devices **111–113** and to the local server computer **110'**. A local temperature control means **182** (e.g. cooling fans) may be included in the infrastructure **180** for controlling the temperatures of the local devices **110'**, **111–113**. A local component security means **183** (e.g. a locked, alarmed cabinet) may be provided for assuring physical security of one or more of the local components **110'**, **111–113** (and also, if desired, of the archived-data storage means and tapes **114**). A local data path integrity checking module **184** may be further included within the local infrastructure **180** for assuring proper interconnections by cable or otherwise between units **110'** and **111–113** so that data is properly transferred from one to the other.

A local infrastructure support program **116** is preferably loaded into the local server computer **110'** for monitoring and managing one or more of the local infrastructure components **181–184** coupled to it and its associated data storage units **111–114**.

A local backup execution program **117** is also preferably installed in the local server computer **110'** for routinely making, or at least requesting, backups of various data files held in the local primary and secondary storage means **111–112**. (Aside: As will be understood from the below discussion, a disadvantageous traffic congestion condition may develop on the network-linking backbone **105** as a result of many primary file servers all trying to backup their files at one time to a shared backup server. To avoid this, backup making is preferably controlled on a domain-wide basis by a backup-scheduler and policy-enforcer which is contained in the box numbered **150.2** and which will be described in more detail below. The local backup execution program **117** sends requests to the backup scheduler/policy enforcer and receives execution commands or permissions from the scheduler/policy enforcer **150.2**. These backup commands/permissions are issued on the basis of a rule base **150.1** that tries to minimize traffic congestion and balance workloads along network-linking backbone **105** by appropriate scheduling.)

A "local" hierarchal storage migration (HSM) control program **118** may also be installed in the local server computer **110'** for managing the migration of less-often used files from primary storage **111** to secondary storage **112**. As explained above, a typical set-up will have one dedicated, HSM file server providing migration services to a designated "group" of primary file servers. Domain **190** can have plural, nonoverlapping "groups" of primary file servers and in such a case, each group will have its own dedicated, HSM file server. When dedicated HSM file servers are used, the hierarchal storage migration (HSM) control program **118** will typically reside only inside the dedicated HSM file servers. (As will be understood from the below discussion, if two HSM servers try to perform their migration operations at the same time, it is possible that such operations will lead

to excessive traffic congestion on the shared network-linking backbone **105**. As such, migration of files between primary and secondary storage is preferably controlled on a domain-wide basis by a migration-scheduler and policy-enforcer which is contained in the box numbered **150.2** and which will be described in more detail below. The local hierarchical storage migration control program **118** sends requests to the migration scheduler/policy enforcer and receives execution commands or permissions from the scheduler/policy enforcer **150.2**. These migration commands/permissions are issued on the basis of a rule base **150.1** that tries to minimize traffic congestion and balance workloads along network-linking backbone **105** by appropriate scheduling.)

A plurality of domain/local exchange agent programs **119** are also preferably loaded in the server computer **110'** for cooperatively interacting with the domain administrating server **150** as will be explained shortly. Note that a filled circle, with a line extending from it to a corresponding software structure, is used to indicate that the software structure is installed on the particular server computer.

Each of the primary (P), secondary (S), backup (B) and archive (A) storage means **111–114** has a local catalog defined within it for identifying the name, location and other attributes of each file stored therein. The local catalog will also typically store information describing each directory full of files or full of subdirectories that is defined therein, and each volume full of directories that is defined therein.

The file-locating information in the local catalog may include a name (ServerName) given to the associated server computer. The file-locating information may also include a set of partition definitions: (a) for partitioning the physical storage media of a given server computer into a set of logical "volumes", (b) for assigning a unique name (VolumeName) to each volume, (c) for indicating the number of files (VolumeFileCount) stored in each volume, (d) for indicating the total storage capacity (VolumeSizeInBytes) of the volume, the amount of used space (VolumeActiveBytes), and the amount of free space (VolumeInactiveBytes).

Volumes are typically subdivided logically into a root directory and a plurality of subdirectories. The file-locating information in the local catalog will usually include a name (DirectoryName) given to each such subdivision and a count of the number of included files (FileCount).

Because each directory can be logically subdivided into subdirectories wherein a desired file might be found, the file-locating information in the local catalog will usually define a "pathname" for uniquely identifying each file according to the path followed from a root point to the subdirectory that holds the file. A typical pathname has it branches separated by the backslash symbol ("\") and takes on the form:

Path=:ServerName\VolumeName\RootDirectory\-Subdirectory\Subdirectory\ . . . \Subdirectory\FileName

The first item in the pathname is the name of the physical server computer that controls the storage drive or drives in which the file is located. The second item is a logical volume name assigned to a logical partition of the local storage means. For Microsoft DOS™ based machines, the volume names of hard drive partitions typically take on a name such as C:, D:, E:, and so forth. The remaining items in the pathname define a path through directories and subdirectories as will be understood by those skilled in the art. The last item is the name of the file being sought.

Aside from storage location and FileName the other attributes indicated in the local catalog may include but are not limited to: (1) File Size (e.g. in number of bytes); (2) File Chronology in terms of Creation date and time, latest Modify or revision date and time, latest read-only Access date and time, and latest Archive date and time; (3) File User information in terms of who is the "Owner" or original creator of the file, who was the LastModifier of the file, who has read/write/execute permission for this file, and so forth.

Yet further attributes may link the particular file to other data structures and provide system-level control and indicator bits such as the following list of Novell-defined attributes: System, ReadOnly, ExecuteOnly, Subdirectory, Archive, Shareable, Compress, Salvageable, Purgeable, Migrated, Indexed, ReadAudit, WriteAudit, ImmediatePurge, RenameInhibit, DeleteInhibit, CopyInhibit, ImmediateCompress, CompressInhibit and Uncompressable. File attributes for other standard network operating systems such as UNIX and Microsoft WindowsNT™ are also contemplated.

The local catalog may be arranged according to many well-known organizations including a tree organization which starts at a root directory and defines a path name from the root directory through subdirectories to a desired file. The below Table 1 gives an example of the kind of information that might be stored in a subdirectory of a local catalog.

TABLE 1

Path=AcctServr\Cvolume\Accounts\New\			4 Files		
File_name	File_size (KBytes)	Last_Rev (yymmdd hh:mm)	By	First_Ver (yymmdd hh:mm)	Owner
dave.doc	1546	931004 09:15	tom	921224 16:45	dave
dave.do1	1297	931105 11:23	tom	921224 12:25	dave
tom.doc	1881	930906 09:15	dave	910115 09:45	tom
paul.doc	1965	931107 11:23	tom	921224 12:25	paul
***					

Note that the information in the local catalog (Table 1) is only for the files stored on the local storage medium (e.g., the primary storage means **111**) and does not cover files stored in other storage media, either at the same network site or elsewhere in the domain.

A dashed bubble at **111.0** is used in FIG. **1** to represent the contents of the local catalog for the primary storage means **111** of the first DAS-managed file-server **110**. It is to be understood that if there is a secondary storage means **112** present within first file-server **110**, such a second storage **112** will have its own local catalog **112.0**. A bubble for the secondary storage local catalog **112.0** is not shown in FIG. **1** due to space limitations. Similarly, the backup storage means **113**, if present, will have its own local catalog **113.0** (not shown) and the archive storage means **114**, if present, will have its own local catalog **114.0** (not shown). Additionally, if files are distributed across plural drives in accordance with RAID technology (**115**), each local catalog may be organized to identify the locations within each of the plural drives where redundant information for a given file is stored.

Although not fully shown, it is to be understood that the second DAS-managed file-server **120** has an internal structure that is generically similar to that of the first file-server **110**. The physical components of the second file-server **120** may be located at a different network site from that of the first file server **110** and the characteristics of the components in the second DAS-managed file-server **120** may differ substantially from those of the first file-server **110**. This is not to say that the second DAS-managed file-server **120** cannot be alternatively located at the same site and/or have substantially similar components as those of the first file-server **110**. Rather it is to indicate that the second DAS-managed file-server **120** is to be thought of as having its own independent structure and that this structure, in its specifics, may be similar to or different from that of the first file-server **110**.

More specifically, it is to be understood although not shown, that the second DAS-managed file server **120** has one or more of its own primary storage means **121**, secondary storage means **122**, backup storage means **123** and archive storage means **124**. A RAID structure **125** (not shown) may or may not be provided within DAS-managed file server **120**. Each of storage means **121–124**, if present in the second DAS-managed file-server **120**, has a corresponding local catalog **121.0–124.0** (not shown).

The combination of local catalogs **121.0–124.0** associated with the second DAS-managed file-server **120** is represented by dashed bubble **12X.0** in FIG. **1**. (In similar vein, the combination of the earlier-described local catalogs **111.0–114.0** associated with the first DAS-managed file-server **110** will be referred to as **11X.0**.)

For purpose of example, it will be assumed that the second DAS-managed file server **120** is located at a second site which is quite remote from the location site of the first DAS-managed file server **110**. Hence the combination of local catalogs **121.0–124.0** associated with the second DAS-managed file-server **120** will be referred to as the second site local catalogs **12X.0**.

In addition to having its own bank of storage devices **121–124**, the second file server **120** has its own infrastructure support system **180'**. Infrastructure support system **180'** is similar to that of the earlier described system **180** with the exception that the second infrastructure support system **180'** is located at the second site together with the remainder of second file-server **120**. Although not shown, the corresponding UPS, temperature control, component security, and data-path integrity-check modules of the second infrastructure **180'** will be respectively referenced as **181'**, **182'**, **183'** and **184'**.

It is to be understood that a local infrastructure support program **126** is installed in server computer **120'** of the second DAS-managed file-server **120** just as infrastructure support program **116** is installed in server computer **110'** of the first site. A symbol for infrastructure support program **126** is not shown in FIG. **1** in order to avoid illustrative clutter. It is to be similarly understood that the second-site server computer **120'** may have a local backup execution program **127** (not shown) installed therein, and a local hierarchical storage migration control program **128** (not shown) installed therein.

Furthermore, the second file server computer **120'** has its own set of domain/local exchange agent programs **129** installed therein. These domain/local exchange agents **129** are used for cooperatively exchanging messages between the domain administrating server (DAS) **150** and portions of second-site server computer **120'** as will be explained below. A symbol for exchange agent programs **129** is shown in FIG. **1** just behind the symbol for domain/local exchange agents **119**.

It is to be understood that physical communication signals between any two or more of the DAS-managed file servers **110, 120, . . . , 140** and the domain administrating server **150** travel along the network-linking backbone **105**. Sets of dash-dot lines are included in FIG. **1** for showing the logical flow of certain communications.

In particular, a first bundle of such dash-dot lines **101** is drawn to represent a first flow of communications between the domain administrating server **150** and the domain/local exchange agents **119, 129, . . . , 149** (the last one belongs to server computer **140'**). The first logical communications flow **101** includes: catalog snapshot data requests and responses; migration and backup scheduling requests/commands; SNMP (Simple Network Management Protocol) reports of status or alerts; and other types of information as will be explained later.

A second such bundle of dash-dot lines **102** represents a second flow of logical communications **102** which take place between the domain administrating server **150** and administrative or user workstations **160, 161, . . . , 170**. The second logical communications flow **102** includes requests for information on domain-wide status and trends as will be explained below.

A third bundle of such dash-dot lines **103** represents a third logical flow of communications which take place between the local catalogs **11X.0, 12X.0, . . . , 14X.0** of respective systems **110, 120, . . . , 140** and a soon-to-be described domain-wide virtual catalog **150.00** (current snapshot) that is defined in the primary storage **151** of the domain administrating server **150**.

As should be already apparent, any additional number of DAS-managed file servers similar to above-described file servers **110** and **120** can be connected to the network-linking backbone **105** and each such additional server can be located at a site remote from the sites of the other servers or at a same site. For purposes of illustration, the third DAS-managed file server **140** is shown as the last in a chain of such file servers **110, 120, . . . , 140**. Like the above-described other file servers **110** and **120**, the third file server **140** is understood to have its own infrastructure **180"**, its own set of data storage means **141–144** (not shown) and its own set of installed programs **146–149** (not shown except for last item). The last named item, **149**, represents the domain/local exchange agent programs **149** of system **140** and a symbol for this collection of field agent programs is shown in FIG. **1** lying beneath the symbol for **129**. The combination of local primary, secondary backup and archive catalogs for system **140** are represented by bubble **14X.0**. The third logical communications flow **103** collects the contents of catalogs **11.X, 12.X, . . . , 14.X** and integrates them into a soon-described, domain-wide virtual catalog **150.00**.

The domain administrating server (DAS) **150** has a client/server type of computer **150'** similar to those of already described servers **110, 120, . . . , 140** with the exception that the domain administrating server **150** is not intended to store individually-owned user files for use by individual network users. Instead, the mass storage means (e.g. **151**) of the domain administrating server **150** is used primarily for storing information related to domain-wide activities.

A first domain-wide activity that is supported by the domain administrating server (DAS) **150** is the maintenance of a current-snapshot of a domain-wide "virtual" catalog **150.00**. Although the non-volatile data storage means **151** of the domain server **150** does not contain all the data stored in all the various data storage means **111, 112, . . . , 143, 144**

of the remainder of the domain **190**, the virtual catalog **150.00** is constructed to create an impression of such a case. Hence the name domain-wide "virtual" catalog is given to the data structure represented by dashed bubble **150.00**.

The information of the domain-wide virtual catalog (current snapshot) **150.00** is held in a domain administrating data/rule base **150.1**. The database portion of this construct **150.1** is preferably of a relational database type so that entries can be conveniently updated and searched according to a variety of known database update and query schemes. One embodiment of the invention uses a relational-style database package bearing the tradename MDBS IV™ which is available from Micro Data Base Systems Inc. of Lafayette, Ind. (U.S. postal zip code 47902).

A domain-wide status-monitor and control program **150.2** is installed in the domain administrating server **150**. One of the domain-wide status monitoring functions of program **150.2** is to: (1) periodically scan the domain **190** and interrogate each DAS-managed file-server **110**, **120**, . . . , **140** regarding the contents of each local catalog **111.0**, **112.0**, . . . , **144.0** that is associated with each of data storage device **111**, **112**, . . . , **144** in the network domain **190**; (2) to collect the file identifying information stored at a given scan time in each such local catalog by way of the network-linking backbone **105**, and (3) to integrate the collected information into the domain-wide virtual catalog **150.00** so that each user file stored in the domain **190** during a given scan-period can be identified by time-of-scan, file-name, location or other relevant attributes simply by consulting the domain wide virtual catalog **150.00**.

Each time a new scan of the domain **190** is carried out, and new information is collected, the older information which was collected by previous scans is preferably retained and re-labeled as belonging to the appropriately-dated previous scan rather than being discarded. A historical collection is thereby created. There will be some point, of course, when it will be desirable or necessary to discard older data. An example is where the used-space of storage means **151** begins to reach maximum capacity. In such a case, nonessential older data should be archived or discarded to make room for more recent data.

The data of each DAS scan is referred to as a "snapshot". After a number of time-spaced snapshots are taken, the domain administrating data/rule base **150.1** defines a historical record for every file in the domain **190**. FIG. **1** shows two previous snapshots **150.01** and **150.02** behind current snapshot **150.00**. There, of course, can be many more.

Each snapshot **150.00**, **150.01**, **150.02**, etc., of the domain-wide virtual catalog should, of course, include information indicating the time of the respective domain-wide scan. The stored snapshot information should also indicate which physical server provided the file-status information and which local catalog served as the source of each file-identifying entry.

Consider the below Table 2 which shows an example of what might be displayed to an inquiring administrator or user when the domain administrating data/rule base **150.1** of the domain server is queried for virtual catalog information.

TABLE 2

Listing= Virtual_Domain.Catalog 99999999994 Files
(Snapshot Period: 900101 to 931130)

File_Source	File_Name	File_Size (KBytes)	Last_Rev (yymmdd hh:mm)	By	. . .
Acct111.0\. . .	dave.doc	1546	931004 09:15	tom	. . .
Acct111.0\. . .	dave.doc	[1544]	931003 17:35	paul	. . .
Acct111.0\. . .	dave.doc	[1543]	931002 14:22	dave	. . .
Acct111.0\. . .	dave.do1	1297	931105 11:23	tom	. . .
Acct111.0\. . .	paul.doc	1965	931107 11:23	tom	. . .
Acct112.0\. . .	tom.doc	1881	930906 09:15	dave	. . .
Acct112.0\. . .	tom.do2	0000	930906 09:15	dave	. . .
AcctBak.0\. . .	dave.doc	1544	931003 11:59	paul	. . .
AcctBak.0\. . .	dave.doc	[1543]	931002 11:59	dave	. . .
AcctBak.0\. . .	dave.doc	[1541]	931001 11:59	tom	. . .
AcctBak.0\. . .	dave.do1	1281	931104 11:59	tom	. . .
AcctBak.0\. . .	tom.doc	1872	930905 11:59	dave	. . .
AcctBak.0\. . .	paul.doc	1953	931106 11:59	tom	. . .
AcctArc.1\. . .	dave.doc	1530	911001 23:55	tom	. . .
AcctArc.1\. . .	dave.do1	1260	921101 23:56	tom	. . .
AcctArc.1\. . .	tom.doc	1850	910901 23:57	dave	. . .
AcctArc.1\. . .	paul.doc	1940	901101 23:58	tom	. . .
AcctArc.2\. . .	tom.do2	1776	900906 09:15	dave	. . .
Mktg121.0\. . .	dave.doc	1544	920704 09:15	tom	. . .
Mktg121.0\. . .	dave.do1	1297	931105 11:23	tom	. . .
***					

The query-results header of TABLE 2 is constructed to resemble the result of a Microsoft-DOS DIR *.* list command, with a first exception being that it names a directory that happens to be very large (99999999994 files). A second exception is that it defines a snapshots-taking period (e.g., 900101 to 931130).

The first column of Table 2 shows the file source pathname as beginning with a file-server name (e.g., Acct**111.0**\ . . . or Mktg**121.0**\ . . .) rather than simply a with a volume or root directory name. The second column shows the file name. Due to space limitations, only the ServerName is shown, but it is understood that the contents of column one can be expanded out to show a full pathname including VolumeName and one or more related directories.

Note that the same file name may appear multiple times in the listing of Table 2, even with identical path names (e.g., "dave.doc"). The difference lies in the date of creation or revision fields. List rows with square brackets around their size field do not have corresponding files still existing within the domain. Rather they are historical shadows that may be